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US Army Corps of Engineers

The Hydrologic Engineering Center

Developing and Managing a Comprehensive Reservoir Analysis Model

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Developing and Managing
a Comprehensive Reservoir Analysis Model[1]

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ABSTRACT

The Corps of Engineers operates over 300 reservoir projects which serve a variety of purposes including flood control, hydropower, water supply, water quality, recreation, and navigation. Corps projects are operated in a wide range of physical environments with numerous operational constraints.

The Corps' Hydrologic Engineering Center (HEC) has developed a generalized simulation model capable of analyzing complex river-reservoir systems. The development of the model, "HEC-5, Simulation of Flood Control and Conservation Systems" (Eichert, 1974, 1975) has been paced by the changing mission of the Corps as well as the evolution of computer systems.

HEC-5 development and management, including code development, testing, documentation, training, and field application experience, will be discussed.

INTRODUCTION

Computer program "HEC-5, Simulation of Flood Control and Conservation Systems", has evolved during the last 16 years (1972-1988) from a flood control only, single event reservoir simulation model to a generalized hydrologic and economic reservoir simulation model with capabilities for flood control, water supply, and hydropower analysis for multi-flood or period of record analysis. HEC-5 has developed in ways which the program's author, Bill S. Eichert, could

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not have anticipated, reflecting both the changing requirements of the Corps of Engineers and the evolution of computer systems.

The first release of HEC-5, May 1973, gave the Corps of Engineers a mainframe based, reservoir simulation model which automated the traditional manual reservoir routing and release decision making computations. This version provided the ability to simulate up to three flood control reservoirs operating for downstream damage centers or reservoirs, with consideration of local flows and hydrologic routing, for a single flood event.

The most recent release, the October 1988 version, provides the Corps with the ability to simulate reservoir system operation for flood control, water supply, and hydropower objectives on both mainframe and personal computers for any configuration of up to twenty reservoirs and thirty-five control points. Current Corps HEC-5 applications include real-time water control as well as planning oriented simulations.

PROGRAM DEVELOPMENT

The original code, written in FORTRAN IV, was developed on 64-bit CDC 7600 computers. The current version has been updated to FORTRAN 77 and development is occurring on a 24-bit Harris mini-computer and 32-bit PCs. Program size has increased from approximately 20,000 lines of code for HEC-5 in 1979 to more than 143,000 lines of code in the six programs that comprise the family of file creation, data checking, and simulation modules that represent the complete 1988 HEC-5 package of programs (see Figure 1).

The code style of the early releases of HEC-5 was typified by a small number of rather lengthy complex subroutines tied together with large catch-all COMMON blocks. In 1978, storage requirements for the program had grown large enough that a subdivision of the code into two separate programs, a simulation module (HEC5A) and an output/economic analysis post-processor (HEC5B), was required.

HEC-5 FAMILY OF PROGRAMS (APRIL 1988)

Name	Program Purpose	Number of Subroutines	Lines of Code
HEC5A	Simulation (Batch)	169	86,000
HEC5B	Output & Economics (Batch)	30	10,000
CKHEC5	Input Checking (Batch)	28	9,600
IN5	Input Creation (IA)	23	10,800
MOD5	Input Modification (IA)	47	25,000
MENU5	Program, I/O Selection (IA)	10	1,600
Total		307	143,000

Figure 1

PROGRAM MODERNIZATION

In 1982, the HEC initiated an analysis of the structure and function of the HEC-5 subroutines and COMMON block structure. The goal of this analysis and subsequent code modernization was to minimize program support efforts, reduce malfunctions, and make future HEC-5 code improvements more manageable. This resulted in segmentation of the HEC5A's 12 major routines into 102 routines with most inter-routine communication accomplished with argument strings.

In addition to creating logic modules which were easier to understand and modify, numerous comments were added to the code with explanations of logic, variable definitions, and notes related to possible future improvements. This type of internal documentation has proven to be a significant aid to both the original program author as well as other HEC staff in making improvements and correcting malfunctions.

The majority of the segmentation work was performed under contract. An in-house run through of the subroutine segmentation process was performed by Ms. Marilyn Hurst, a programmer assigned full time to the HEC-5 program, to better estimate the time required and the process necessary for the remaining segmentation. The task of designing the COMMON blocks and argument strings as well as completing the segmentation process was then contracted to the staff of the Hydraulics Lab of the University of California at Davis (UCD). Their experience with FORTRAN programming for a variety of micro-computers used for data collection and analysis proved quite useful when the HEC began the process of adapting HEC-5 to personal computers.

In a further effort to streamline the program logic, several new subroutines were created to centralize logic, such as that related to the program's determination of reservoir releases. This was necessary because during the first 10 years of development of HEC-5 the logic for the prioritization and selection of many of the seventeen possible reservoir releases had been scattered throughout the code. In addition several essential routines were rewritten to clarify logic that had become difficult to understand after years of code

improvements by several authors, each with a different style and understanding of the program.

Also improved in the modernization process was the HEC-5 optional "trace output" capability. This program feature provides diagnostic output showing, the normally unseen, internal computations. The trace feature is selectable by subroutine, simulation time period, and data model location (ie, reservoir or control point). The modernization activity enhanced the trace output feature by including variable name labels above the numeric trace output for easier debugging. In addition, the origin of the trace output (subroutine names and statement numbers) is shown for each trace output. We have found the trace output feature to be indispensable in the development and maintenance of a large, complex, program such as HEC-5.

The net result of the HEC-5 modernization effort has been the development of a program which is significantly easier to understand, to maintain and to adapt to a variety of computer systems. Future code enhancements, including the addition of hydraulic routing and graphical interfaces, will no doubt benefit from these efforts.

ADAPTATION TO MICRO COMPUTERS

The process of adapting HEC-5 from the CDC mainframe computers to the personal computer actually began with the installation of HEC-5 on the HEC's Harris 500 mini-computer in 1980. The change from the CDC 64-bit word size to the Harris' 24-bit computer required the selected use of double precision integer variables and resulted in an effort to modify HEC-5's use of mixed mode arithmetic statements to avoid the use of double precision statements. Further PC related code enhancements were developed as a result of adapting HEC-5 for use with the less forgiving compilers of an HP 9000 mini and an Amdahl mainframe computer. These adaptations, coupled with the revised subroutine structure and improved COMMON blocks, provided the basis for the successful adaptation of HEC-5 to micro computers.

The HEC contracted with Mr. Carl Franke, an electrical engineer and micro-computer hobbyist, to make the adaptation of HEC-5 to an IBM PC/XT. Mr. Franke had worked on the program while a UCD employee, and had adapted it to the HP and Amdahl computer systems for the Corps. He investigated four PC level FORTRAN compilers and found that the LAHEY FORTRAN 77 (LAHEY,1987) compiler was the only PC level FORTRAN compiler with a complete enough implementation of FORTRAN 77 to accommodate HEC-5's large number of arguments and continuation lines.

Originally, it was anticipated that the implementation of a large mainframe type program such as HEC-5 to the micro computer environment would be made at the expense of program capabilities and by significant reductions in array sizes. Mr. Franke was able, however, to successfully implement the September 1986 program on an IBM PC/XT while maintaining HEC-5's full capabilities, with only moderate reductions in array sizes through the use of program overlays.

This first HEC-5 PC release utilized a complex nested overlay scheme to fit the program within the 640 Kb MS-DOS memory limit. The October 1988 PC version (HEC, 1988), however, provides full mainframe array sizes and comparable execution times without overlaying by using A.I. Architects OS/286 (A.I. ARCHITECTS, 1988) extension to MS-DOS and extended memory. (See Figure 2)

MAINTENANCE SOFTWARE

As program code is revised and new capabilities are added to a large program such as HEC-5, the need arises for a systematic, trackable, software maintenance system. The primary tool that is being currently utilized for updating and maintaining the HEC-5 package of software is OPCODE's "Historian Plus" (OPCODE, 1985) program, which is available on the HEC Harris 1000 computer. The Historian program provides a systematic procedure for tracking program modifications; thus, as its name implies, it provides a "history" of the programs development. With HEC-5 code modifications developed simultaneously at the HEC by three staff members, in addition to code changes provided by contractors, the usefulness of a systematic approach is obvious.

CURRENT HEC-5 PC PERFORMANCE

ARRAY SIZES

	Mainframe	1986 PC	1988 PC
Number of Reservoirs	20	15	20
Number of Control Points	35	15	35
Number of Time Periods	2,000	200	2,000
Number of Power Plants	12	9	12

Figure 2

In order to better understand the many lines of program code that constitute the HEC-5 package of programs, several other utility programs have been developed for use as programming tools. One of the most useful is the HEC developed "FORTRAN Source Inventory and Renumbering (FSIR)" program (HEC,1966). FSIR is utilized primarily to map the location and function of program variables. It creates, for all variables in a FORTRAN source deck, files which contain the FORTRAN statement numbers, subroutine name and a code which indicates the type of FORTRAN statement where the variable was used. In addition, FSIR is used to renumber FORTRAN statement numbers, which becomes necessary when many changes are made to HEC-5. These capabilities have proven to be invaluable tools in modifying and maintaining HEC-5.

PROGRAM TESTING

An important aspect of the management and development of a complex program, such as HEC-5, is the creation and use of test materials for the verification of code changes. In the case of HEC-5, it is not entirely unexpected that revisions to program logic related to water supply simulation could effect hydropower or flood control release determinations. The HEC initially developed a series of ten standard data sets which provided testing for many of the programs options. These standard data sets have also been utilized for installation verification and benchmarking when HEC-5 has been adapted to other computer systems.

As the number of program options increased, it became obvious that further development of test data sets would be of value both for verification and training purposes. Three additional groups of data sets were developed to provide testing for HEC-5's gate regulation, water supply and hydropower simulation capabilities. An additional collection of flood control test data sets are currently under development. Upon completion of this effort approximately one hundred standard data sets will be available for verification and for use as training examples. In addition to the standard test data sets, training course workshop problems and several large field application data sets are utilized periodically for testing.

DOCUMENTATION AND TRAINING

The HEC has always endeavored to provide suitable documentation and training for each of its major programs. Current HEC-5 documentation includes: a Users Manual (HEC, 1982); a separate Input Description (HEC, 1988), which is updated once or twice each year to reflect program developments; and Training Documents for Water Supply (HEC, 1985) and Hydropower (HEC, 1983) applications. In addition, users manuals are available for HEC-5 auxilarly programs; CKHEC5 (HEC, 1987), a data checking program; INFIVE (HEC, 1987), an interactive input preparation program; and INCARD (HEC, 1983), a flow conversion program. In addition to these documents, a Programmers Manual, as well as a revised training document for hydropower and a new document of flood control applications are in preparation.

Training related to computer program HEC-5 is offered in a two week course titled "Reservoir System Analysis" at the HEC in Davis, CA every other year.

FIELD APPLICATIONS

HEC staff members provide HEC-5 field application support to Corps of Engineers offices upon request. Usually HEC assistance is sought by offices for a number of reasons including those without the necessary inhouse HEC-5 expertise or for those studies which require code modifications to extend or add new program capabilities. From a program management point of view, the HEC welcomes the opportunity to involve staff members in practical engineering applications. These are often opportunities to provide informal at-site training, develop new program capabilities, improve program documentation, or develop new training materials.

Corps of Engineers field applications utilizing HEC-5 which have required extensive HEC staff assistance in the past year have included: a period-of-record water supply analysis of the Rio Grande Basin in New Mexico, a navigation/hydropower study for the Han River Basin in South Korea, a flood control study for the Savannah River Basin in Georgia and South Carolina, real-

time water control for the Allegheny River in Pennsylvania, and a period-of-record analysis for system power in Alabama, Georgia and South Carolina.

An example of a recent HEC-5 application is shown in Figure 3, which is a schematic diagram of an HEC-5 model developed to provide real-time reservoir operation for Corps projects in the Allegheny River Basin near Pittsburgh, PA. The HEC-5 model developed for this application interfaces with other HEC software which provides forecasted flows from observed and forecast precipitation. The simulation interval for this analysis is three hours.

Another example is shown in Figure 4, which is a schematic diagram of an HEC-5 model developed to simulate system hydropower production in ten of the Corps projects within the South Eastern Power Administration (SEPA). This model is being utilized in a planning mode to evaluate proposed changes in reservoir operation to reflect the impact of water supply, recreation, and navigation on system power production. The period of analysis for this study is about sixty years and the simulation interval is weekly.

PROGRAM SUPPORT

Program support in the form of hotline assistance for both engineering and programming assistance is available to the Corps of Engineers and other federal agencies. At-site training courses, application assistance and program modifications are also provided to Corps offices. Mr. Richard Hayes is the Engineer in charge of providing hotline user support and is the principal Engineer providing field application assistance for HEC-5. Non-federal support for HEC-5 users, including program distribution, users assistance, and engineering is available through several engineering firms.

ALLEGHNEY BASIN
HEC-5 MODEL SCHEMATIC

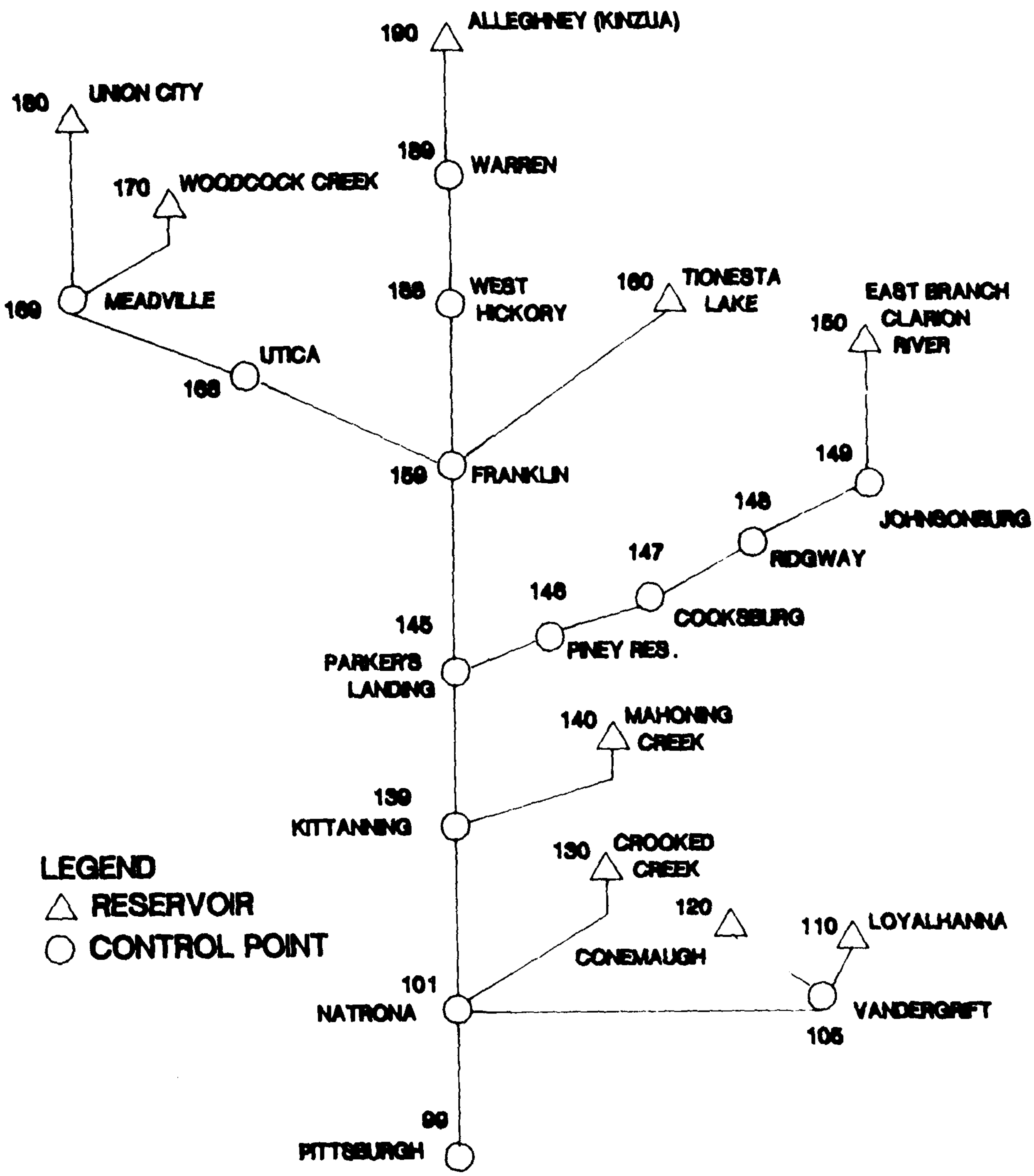

Figure 3

SAD POWER SYSTEM
HEC-5 MODEL

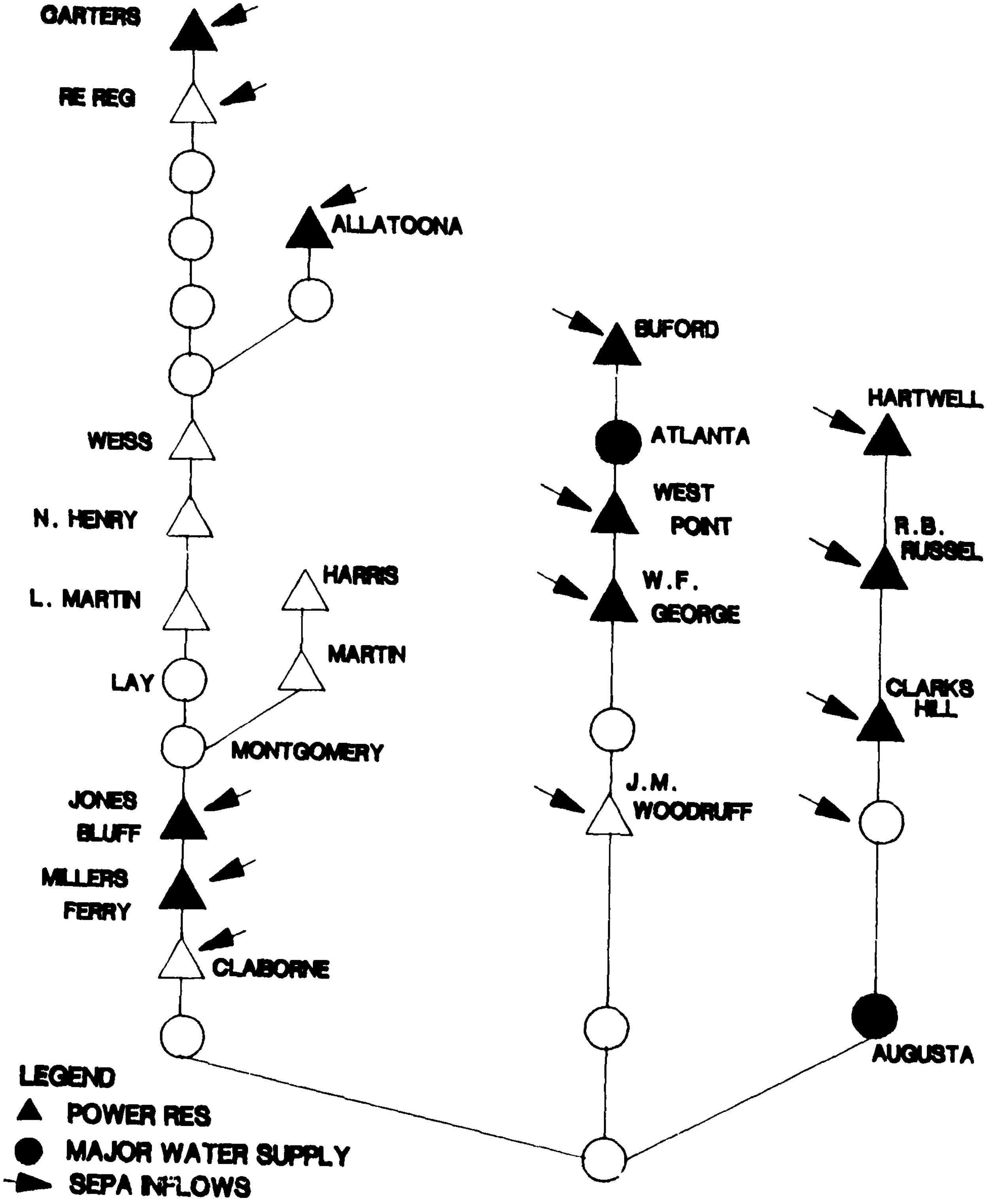

Figure 4

LITERATURE CITED

A.I. Architects, Inc., 1988. OS/286 Documentation.

Eichert, Bill S., 1974. HEC-5C, A Simulation Model for System Formulation and Evaluation.

Eichert, Bill S., 1975. Hydrologic and Economic Simulation of Flood Control Aspects of Water Resources System.

Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1966. FORTRAN Source Inventory and Renumbering.

Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1980. Application of the HEC-5 Hydropower Routines. Training Document No. 12.

Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1982. HEC-5, Simulation of Flood Control and Conservation Systems, Users Manual.

Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1983. INCARD, Flow Conversion for HEC-5, Users Manual.

Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1985. Water Supply Simulation Using HEC-5, Training Document No. 20.

Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1987. INFIVE, Interactive Input Preparation Program for HEC-5, Users Manual.

Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1987. CKHEC5, Input Data Checking Program for HEC-5, Users Manual.

Hydrologic Engineering Center, U.S. Army Corps of Engineers, 1988. HEC-5, Simulation of Flood Control And Conservation Systems, Exhibit 8 of Users Manual, Input Description.

Lahey Computer Systems, Inc. 1987. Fortran 77 Language System.

Opcode, Inc, 1987. Historian™ Plus, Reference Manual.

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